Name ___________________________________ AP Chemistry

Phosphoric Acid in Cola Drinks

Introduction

Many soft drinks contain phosphoric acid (H_3PO_4), which imparts a “pleasant tartness” to beverages and keeps the beverages carbonated. In this experiment, the concentration of phosphoric acid in commercial colas will be determined using an acid-base titration and a visual indicator. The titration of phosphoric acid will be carried out using a sodium hydroxide solution whose concentration will be previously determined also using a visual indicator.

Strong acids are completely ionized in aqueous solution whereas weak acids are only partially ionized in aqueous solutions. A dynamic equilibrium exists between the molecular and ionized forms of the weak acid, as represented in the following equation:

$$HA\ (aq) + H_2O\ (l) \leftrightarrow H_3O^+\ (aq) + A^-\ (aq)$$

The equilibrium expression for this reaction is shown below, where K_a is the acidity constant for the weak acid:

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

The acid neutralization reaction for a weak acid titrated by a strong base is given below:

$$HA\ (aq) + OH^-\ (aq) \leftrightarrow H_2O\ (l) + A^-\ (aq)$$

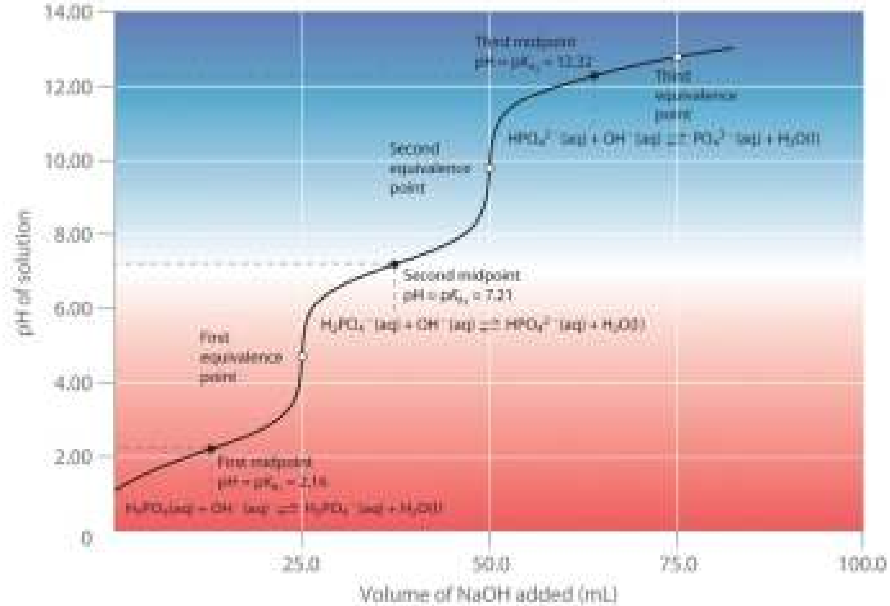
The concentration of HA progressively decreases whereas the concentration of A^- progressively increases. The equivalence point is where weak acid has just been neutralized by the base and the number of moles of acid is equal to the number of moles of base. The volume of base delivered can be used with the base concentration to calculate the amount of weak acid in the initial sample.

Polyprotic acids have more than one dissociating proton per molecule. The reaction showing the dissociation of each of these protons has its own value of K_a as shown below for phosphoric acid, H_3PO_4, a triprotic acid:

$$H_3PO_4\ (aq) + H_2O\ (l) \leftrightarrow H_3O^+\ (aq) + H_2PO_4^-\ (aq) \qquad K_{a1} = 7.5 \times 10^{-3}$$

$$H_2PO_4^-\ (aq) + H_2O\ (l) \leftrightarrow H_3O^+\ (aq) + HPO_4^{2-}\ (aq) \qquad K_{a2} = 6.2 \times 10^{-8}$$

$$HPO_4^{2-}\ (aq) + H_2O\ (l) \leftrightarrow H_3O^+\ (aq) + PO_4^{3-}\ (aq) \qquad K_{a3} = 2.2 \times 10^{-13}$$



If the values of K_{a1}, K_{a2}, and K_{a3} are separated from each other by several orders of magnitude, the dissociation may be regarded as taking place in a stepwise fashion (i.e. all H_3PO_4 molecules are transformed to $H_2PO_4^-$ ions before any substantial amount of HPO_4^{2-} is formed). The titration curve for phosphoric acid is given above; the equivalence points (i.e. locations where the base has neutralized a single acid species) are clearly marked.

In this experiment, you will be analyzing an unknown solution of phosphoric acid that contains the equivalent amount as found in a cola drink by titrating a sample of the solution with standardized NaOH. You will use two different indicators in this titration: methyl orange and phenolphthalein. Methyl orange changes from red to yellow when the pH changes from 3 to 5 while phenolphthalein changes from colorless to pink when pH changes from 8 to 10.

Prelab Questions

1) The first equivalence point in the titration of cola with 0.0110 M NaOH comes after the addition of 19.60 mL of base to 20.00 mL of acid solution. What is the initial concentration of the phosphoric acid in the cola drink?
2) You will be first titrating to the first equivalence point and then you will titrate to the second equivalence point. Using the titration curve of phosphoric acid above and the pH ranges of the indicators, determine which indicator, methyl orange or phenolphthalein, should be used to find which equivalence point.
3) Write the balanced reaction equations for the reaction of phosphoric acid and sodium hydroxide at the first equivalence and then at the second equivalence.
4) What is meant by a standardized solution of sodium solution (may have to use your textbook or Google)?

Procedure

1) Obtain ~150 mL of standardized 0.01X NaOH in a beaker. Record the molarity.
2) Obtain a burette with a tip along with a ring stand with a burette holder. Also get an empty waste beaker.
3) Place the burette into the burette hold. Make sure the stopcock is in the closed position, perpendicular to the burette. Fill the burette with ~10 mL of DI water. Use a funnel to help fill the burette if needed.
4) Turn the stopcock to the open position, or parallel to the burette, and along the water to run through the tip into an empty beaker. Make sure that water is not leaking from anywhere on the burette.
5) Close the stopcock and add ~5 mL of standardized NaOH to the burette. Remove the burette from the burette holder. Rinse the burette as shown by your instructor.
6) Repeat step 5 once more with another 5 mL of standardized NaOH.
7) Place the burette back into the burette holder and fill the burette with ~50 mL of standardized NaOH. Then allow a few milliliters of base out of the tip into the waste beaker to remove any waste beaker.
8) Record the initial volume of the base to two decimals place. It does not have to 0.00 mL.
9) Obtain an Erlenmeyer flask and transfer 25.00 mL of the unknown phosphoric acid solution to the flask using a volumetric pipette. Follow the instructor's guidelines in using volumetric pipettes.
10) Add 2-3 drops of methyl orange to the flask.
11) Place the flask under the burette with a white piece of paper under the flask. Add ~1 mL of the base from the burette and swirl the solution.
12) Continue to add 1 mL increments of base to the unknown acid solution until the solution turns yellow for a brief moment. Make sure to swirl the flask after each addition of base.
13) Slow down and add the base dropwise until the solution turns yellow and remains yellow.
14) Record the final volume of base.
15) Refill the burette with standardized NaOH and let a few milliliters base out of the tip into the waste beaker.
16) Obtain another flask of unknown phosphoric acid solution as described in step 9. Then add 2-3 drops of methyl orange to the flask.
17) Repeat step 12-14 with the second flask of unknown acid solution.
18) Refill the burette with standardized NaOH and let a few milliliters base out of the tip into the waste beaker.
19) Obtain another flask of unknown phosphoric acid solution as described in step 9. Then add 2-3 drops of phenolphthalein to the flask.
20) Place the flask under the burette with a white piece of paper under the flask. Add ~1 mL of the base from the burette and swirl the solution.
21) Continue to add 1 mL increments of base to the unknown acid solution until the solution turns pink for a brief moment. Make sure to swirl the flask after each addition of base.

22) Slow down and add the base dropwise until the solution turns pink and remains pink.
23) Record the final volume of base.
24) Refill the burette with standardized NaOH and let a few milliliters base out of the tip into the waste beaker.
25) Obtain another flask of unknown phosphoric acid solution as described in step 9. Then add 2-3 drops of phenolphthalein to the flask.
26) Repeat step 20-23 with the second flask of unknown acid solution.

Results

Molarity of Standardized NaOH: ______________________ M

	Methyl Orange		**Phenolphthalein**	
	Trial 1	*Trial 2*	*Trial 1*	*Trial 2*
Initial Volume				
Final Volume				
Volume of base (mL)				
Volume of base (L)				
Moles of base				
Moles of acid				
Volume of acid	0.0250 L	0.0250 L	0.0250 L	0.0250 L
[H_3PO_4]				
Average Concentration				

Calculations

1) Using the volume in liters and concentration of base, calculate the moles of base. Record the moles in the Data Table for each trial.
2) The color change is assumed to occur at the equivalence point so the moles of base is equaled to the moles of acid. Fill in the moles of the acid in the Data Table.
3) Determine the [H_3PO_4] by dividing the moles of acid by the volume of the acid. Record the [H_3PO_4] for each trial in the Data Table.
4) Average the [H_3PO_4] for all the trials for each indicator.

Postlab Questions

1) How do the concentrations of the phosphoric acid compare for each indicator?
2) Sodas are generally considered to be bad to consume. What are some of the biological effects of consuming cola sodas? In terms of your knowledge of acids and bases, explain how the phosphoric acid could cause some of these effects.